A Study to Evaluate Latent Mortality Associated with Passage through Snake River Dams, 2005

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EXECUTIVE SUMMARY

During the 2005 study year, the National Marine Fisheries Service constructed a new fish-tagging facility at Lower Granite Dam. After construction was finished, we began tagging fish to evaluate possible latent mortality (previously termed "extra mortality") associated with passage of yearling hatchery Chinook salmon smolts through Snake River dams.

A concrete slab for the new facility was poured at Lower Granite Dam in early April. Installation of trailers for the facility followed, and construction was completed with the addition of plumbing and electrical components to the trailers. Because of construction delays, fish tagging began on 4 May, approximately 2 weeks after our planned start date.

On 7-8 May, following several heavy rainstorms, turbidity of the Snake River increased dramatically. Highly turbid water generally forces smolts to flee rapidly downstream, and this appeared to have occurred, since after 8 May, fish numbers fell to very low levels and never rebounded. Because of the low numbers of fish, tagging ended on 19 May after only 7 of 10 planned releases were made. Because the tagging effort began late, and turbid conditions developed within a few days after tagging started, we were able to tag only 47,710 of the 301,000 fish we originally planned to release for this study.

Tagged groups of fish were designated as IH for release to the Ice Harbor Dam tailrace with transport, LG for release to the Lower Granite Dam tailrace with transport, and LN for release to the Lower Granite Dam tailrace with no transport. Between about 12 and 20% of the numbers of fish required by the study protocol were released for each study group. Respective detection rates at McNary Dam for the three release groups were 35.1, 27.0, and 27.1% for the Ice Harbor Dam transport (IH), Lower Granite Dam transport (LG), and Lower Granite Dam reference (LN) groups.

Bonneville Dam will serve as the principal adult recovery site for this study. Using this site for adult recovery will maximize SARs for analysis by avoiding loss of adults to mortality and fisheries further upstream. Data acquired from other areas will be considered ancillary. Adults from 2005 releases will begin returning in 2006 (jacks), and all adult returns will be complete in 2008.

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INTRODUCTION

Snake River spring/summer Chinook salmon *Oncorhynchus tshawytscha* abundance declined precipitously after completion of the Federal Columbia River Hydropower System (Raymond 1979; Schaller et al. 1999). The initial decline occurred in the early 1970s as Lower Granite, Little Goose, Lower Monumental, and John Day Dams were added to the existing hydropower system. This early decline was roughly proportional to the direct mortality suffered by smolts during downstream migration through the completed system.

With the installation of structural improvements at dams, and the initiation of operational procedures designed to enhance juvenile fish survival (Williams and Matthews 1995), direct smolt mortality has decreased considerably over the past two decades (Williams et al. 2001). However, despite substantial gains in dam passage survival rates, the adult return rates of Snake River spring/summer Chinook salmon have not increased to levels that existed prior to dam construction.

One of the most important and enigmatic questions currently facing the region is whether or not migration through the hydropower system, as currently configured, causes mortality to anadromous salmonid smolts that is not expressed until after they have passed through the system. This hydropower-related latent mortality (formerly termed "extra mortality") was hypothesized during the Plan for Analyzing and Testing Hypotheses (PATH), a recovery planning process involving over a dozen local, state, and federal agencies. This hypothesis was thought to explain the relative change in productivity calculated for Snake River basin spring/summer Chinook salmon populations compared to populations downstream from McNary Dam after construction of John Day, Lower Granite, Little Goose, and Ice Harbor Dams (Schaller et al. 1996).

Evidence from spawner and recruit data indicated that productivity declined more for upriver stocks, which were most affected by hydropower development, and that this decline occurred primarily after completion of the three final dams on the Snake River. Further, the differential decline was greater than could be explained by differences in direct mortality caused by the additional dams. Schaller et al. (1999) argued there was little evidence that factors unrelated to the hydropower system could account for the differences in productivity and survival between upstream and downstream stocks. On the other hand, Zabel and Williams (2000) and Hinrichsen (2001) questioned this conclusion and provided evidence that several other factors could be at least partially responsible for these differences.

Scientific debate surrounding this issue will continue unresolved in the absence of experimental data. The goal of this study is to determine whether migration through Snake River dams and reservoirs causes latent mortality in Snake River yearling Chinook salmon smolts. Specifically, the study will attempt to determine whether complete life-cycle survival downstream from McNary Dam is significantly higher for yearling Chinook salmon released into the tailrace of Ice Harbor Dam than for counterparts released into the tailrace of Lower Granite Dam, where migrating smolts must pass three additional Snake River dams and reservoirs.

METHODS

Sampling and Tagging of Juveniles

We collected and PIT-tagged hatchery Snake River spring/summer Chinook salmon at Lower Granite Dam. Collection and handling techniques, including use of the recirculating anesthetic water system, followed the methods described in Marsh et al. (1996, 2001). Tagging for each replicate was conducted in 2-d blocks. The first day of each block involved tagging for the reference group, to be released into Lower Granite Dam tailrace with no transport (LN). After tagging, these fish were sent to a holding tank for 24-h.

On the second day of each block, we tagged fish for the two remaining groups: the Ice Harbor Dam tailrace release (IH) and Lower Granite Dam tailrace release (LG), both of which were transported by truck prior to release. Because truck drivers could work for only a limited number of hours each day (for safety reasons), all tagging had to be completed by 1600 PDT. This allowed the truck driver returning fish to Lower Granite Dam enough time to drive back to his base of operations within the allotted time.

All fish were released at approximately the same time. The IH fish were released upon arrival at Ice Harbor Dam (approximately 2000 hours), with releases made to the tailrace through the bypass outfall pipe of the juvenile fish facility. A circuitous route was devised for the truck carrying the LG release group so that these fish were returned to Lower Granite Dam at the same time the IH release group was arriving at Ice Harbor Dam. The LG group was released to the tailrace through a pipe that runs along the top of the bypass outfall pipe at the Lower Granite Dam juvenile fish facility. Following the release of the LG group, the LN group was immediately released through the same pipe.

Evaluation will be based on annual smolt-to-adult return ratios (SARs) of the LG:IH groups (LG/IH ratios). Note that LG/IH is a measure of differential "post-McNary" survival; as such, it is analogous to the *D* parameter, a ratio of SARs for fish transported below Bonneville Dam to fish detected passing Bonneville Dam. Thus, an LG/IH ratio significantly less than 1.0 will indicate significant latent mortality for fish that passed through the hydropower system between Lower Granite and Ice Harbor Dams.

Release group sizes were designed to provide an 80% probability ($\beta = 0.20$) of detecting a significant difference between groups (i.e., if LG/IH < 1.0) using a one-sided hypothesis test with $\alpha = 0.05$. Thus, if the true LG/IH ratio is less than or equal to 0.80 (i.e., survival is at least 20% lower for LG fish), and the SAR of IH fish is at least 1.5%, then the difference in survival can be identified as statistically significant (see below).

Required numbers for release were derived by determining the required precision around the estimated LG/IH such that the one-sided confidence interval on the true LG/IH ratio did not contain the value 1, or the confidence interval of the true natural-log transformed LG/IH ratio, ln(LG/IH), did not contain 0. If the confidence interval excludes 1.0, then we can reject the null hypothesis, that there is no difference in life-cycle survival (the true value of LG/IH may be 1.0). Therefore, the number of fish needed was determined in the following manner:

$$\ln\left(\frac{\mathrm{LG}}{\mathrm{IH}}\right) - (t_\alpha + t_\beta) \times \mathrm{SE}\left[\ln\left(\frac{\mathrm{LG}}{\mathrm{IH}}\right)\right] \approx 0 \tag{1}$$

and

$$\mathrm{SE}\left[\ln\left(\frac{\mathrm{LG}}{\mathrm{IH}}\right)\right] \approx \sqrt{\left(\frac{1}{\mathrm{n_{IH}}} + \frac{1}{\mathrm{n_{LG}}}\right)} = \sqrt{\frac{2}{\mathrm{n}}} \tag{2}$$

where n is the number of adult returns per treatment (n for Ice Harbor Dam and Lower Granite Dam tailrace groups set equal for simplicity). The previous two statements imply that the required number of adults is:

$$\mathrm{n} \approx \frac{2(t_\alpha + t_\beta)^2}{\left(\ln\left(\frac{\mathrm{LG}}{\mathrm{IH}}\right)\right)^2} \tag{3}$$

As described above, if we set $\alpha = 0.05$, and $\beta = 0.20$, and expect an SAR for IH fish of at least 1.5%, then the sample sizes needed are listed as follows (N_{IH} is the number of juveniles needed at Ice Harbor; N_{LG} the number needed at Lower Granite Dam).

true LG/IH	n	N_{IH}	$N_{LG} = N_{IH}/(LG/IH)$	N_{Total}
0.80	249	16,600	20,750	37,350

The above calculations provide only the number of juveniles that need to be *detected* at McNary Dam. Detections are obtained by releasing tagged fish upstream from McNary Dam and counting the number detected at the dam. However, because mortality occurs en route, before release groups arrive at McNary Dam, and only a portion of the fish arriving at the dam will be detected, greater release numbers were needed to provide the required number of detections for analysis. Thus, to determine total tagging requirements, we used assumed probabilities of survival to and detection at McNary Dam for each study group.

Based on survival estimates from previous years, we assumed survival probabilities of 0.929 from Ice Harbor tailrace to McNary Dam (IH group) and 0.723 from Lower Granite tailrace to McNary Dam (LG group). In 2000, estimated detection probability in the collection system at McNary Dam for yearling Chinook salmon smolts was 0.300. Therefore, we conservatively assumed a detection probability of 0.250 for study smolts passing McNary Dam.

Thus, to realize the necessary number of study fish detections at McNary Dam required releasing approximately 71,475 fish (16,600/0.929/0.250) into the Ice Harbor Dam tailrace and 114,799 fish (20,750/0.723/0.250) into the Lower Granite Dam tailrace. An additional 114,799 non-transported fish were required for release directly into the Lower Granite Dam tailrace to control for potential transport effects. This brought the total tagging requirement to 301,073 fish.

Recovery of Adult Study Fish at Bonneville Dam and Data Analyses

Bonneville Dam will serve as the principal adult recovery site for this study. Using this site for adult recovery will maximize study SARs by avoiding upstream passage mortality and mainstem fisheries. Data acquired from other areas will be considered ancillary. To analyze results, statistical tests will be applied when adult returns for the study are complete (in 2008 for 2005 releases). For each year of releases, the study will provide a seasonal LG/IH estimate. Confidence intervals for LG/IH ratios will be calculated using the ratio (survival) estimate of Burnham et al. (1987) and its associated empirical variance.

RESULTS AND DISCUSSION

The large number of tagged fish needed for this study required construction of a new tagging facility. However, delays in construction of the new facility affected our tagging effort in two ways. First, we began tagging on 4 May, approximately 2 weeks later than planned. Second, because of uncertainty in when the tagging would start, we were unable to hire sufficient seasonal personnel. Therefore, while numbers of hatchery Chinook salmon passing Lower Granite Dam were still high when tagging began, the number of seasonal personnel available when tagging began was considerably lower than necessary to take advantage of fish abundance.

During the first week (4 days) of tagging (Table 1), we tagged an average of 5,991 fish per day (11,982 fish per replicate block). Prior to the second week of tagging during 7-8 May, heavy rains caused the turbidity of the river to increase dramatically (Figure 1). Generally, high turbidity causes fish in front of the turbid water to flee rapidly downstream, effectively scouring the river of fish. After the turbid water passed the dam, our tagging numbers decreased to an average of 2,073 fish per day (over 9 days), even though our tagging effort did not decrease. We decided to terminate tagging for 2005 after the seventh replicate block because we were only able to tag a total of 3,173 fish for all three release groups in that block.

Our study design was based on comparisons of fish detected at McNary Dam, so juvenile fish were monitored as they migrated downstream after release (Table 2). The purpose of the LN group was to provide a reference for potential effects of transport (trucking). Based on 2005 results, there did not seem to be any effect of trucking at the juvenile stage, as the LN and LG groups were detected at McNary Dam at nearly the same rate.

Adults from 2005 releases will begin returning in 2006 (jacks), with complete adult returns in 2008.

Table 1. Dates of collection, PIT-tagging, and release of hatchery yearling spring/summer Chinook salmon for the latent mortality study at Lower Granite Dam in 2005. Numbers of fish released are also shown.

Collection date	Tag date	Release date	Number of fish released	Release number per block
2 May	3 May	4 May	5,796	
3 May	4 May	4 May	6,913	12,709
4 May	5 May	6 May	5,078	
5 May	6 May	6 May	6,176	11,254
8 May	9 May	10 May	5,090	
9 May	10 May	10 May	2,720	7,810
10 May	11 May	12 May	1,421	
11 May	12 May	12 May	1,951	3,372
12 May	13 May	14 May	1,584	
13 May	14 May	14 May	3,398	4,982
15 May	16 May	17 May	2,701	
16 May	17 May	17 May	1,709	4,410
17 May	18 May	19 May	1,490	
18 May	19 May	19 May	1,683	3,173

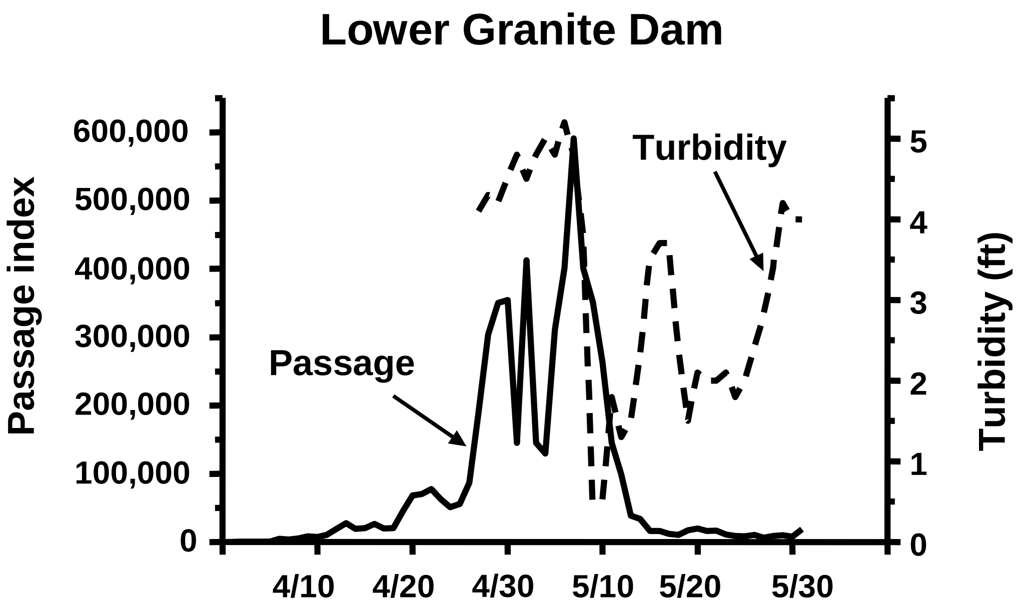

Figure 1. Passage index of yearling Chinook salmon and turbidity measured by Secchi disk (ft) at Lower Granite Dam, 2005.

Table 2. The number of PIT-tagged hatchery yearling spring/summer Chinook salmon released at Lower Granite Dam after trucking (LG), released at Lower Granite Dam without trucking (LN), and at Ice Harbor Dam (IH) for evaluation of extra mortality in 2005. The number and percent detected at McNary Dam is also shown.

Release group	Release number	Detected number	Percent detected
LG	13,506	3,644	26.98
LN	22,934	6,221	27.13
IH	10,912	3,831	35.11

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